Evidence for a Gas-Rich Major Merger in a Proto-Cluster at $z = 2.5$

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Properties of galaxies seen in the local universe strongly depend on their surrounding environments, as is well known from the morphology–density relation. Early-type galaxies are frequently observed in high-density regions such as clusters and late-type galaxies are common in low-density regions. Such spatial segregation could be related to formation processes and subsequent quenching mechanisms of star formation, which probably take place at high redshift. Given high number densities of star-forming galaxies in proto-clusters at $z>2$, we naturally expect a high frequency of major-merger events.

We have conducted CO $J=1-0$ emission line observations with the Jansky Very Large Array (JVLA) [1]. The target field is a proto-cluster at $=2.53$, USS1558-003, including 20 Hα emitters (HAEs). We have detected the CO emission line from three galaxies (ID 191, ID 193, and ID 213) of our sample. Using MIPS 24 μm and JVLA 33 GHz images, we derive a total infrared (IR) luminosity of $L_{IR} = 5.1 \times 10^{12} L_{\odot}$ for ID 193. Assuming that the bulk of the IR luminosity is powered by star formation, we find ID 193 to have a high SFR of $886\, M_{\odot}\, yr^{-1}$.

The separation between ID 191 and ID 193 is about 4 arcsec corresponding to 32 kpc in the physical scale and the velocity offset is $300\, km\, s^{-1}$, suggesting that they are probably in the initial stage of a merger. Moreover, the derived SFR of $886\, M_{\odot}\, yr^{-1}$ in ID 193 is higher by a factor of about seven with respect to the M_*-SFR relation of normal HAEs (*main~sequence*) and is similar to that of SMGs, where extremely high star formation is thought to be driven by major mergers. In Figure 1, we also plot ID 193 on the L_{IR}-L'_{CO} diagram to compare this with other populations taken from the literature. ID 193 has a higher IR luminosity compared to normal star-forming galaxies at a fixed CO luminosity and are situated close to the regime of low-redshift ULIRGs.

Given a violent star-formation activity (SFR=886 $M_{\odot}\, yr^{-1}$), high L_{IR}/L'_{CO} ratio (high SFE) and red optical color, we interpret ID 193 as a star-bursting galaxy driven by a gas-rich merger with ID 191 or another galaxy.
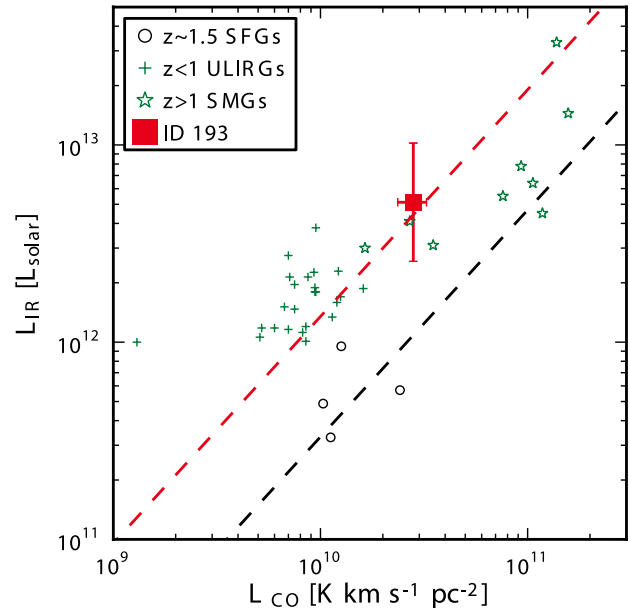

Figure 1: IR vs. CO $J=1-0$ luminosities of ID 193 (red square) along with SMGs at $z>1$ (green stars: [2,3,4]), ULIRGs at $z<1$ (green crosses: [5]), and optical/near-IR selected star-forming galaxies at $z>1$ (black circles: [6]). Dashed black and red lines show the best-fitting relations for normal star-forming galaxies and luminous mergers [7].

References

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